

**WHAT IS CLAIMED IS:**

- 1                   1.     A process for forming a film of material from a substrate, said  
2 process comprising steps of:  
3                   introducing particles through a surface of a substrate to a selected  
4 depth underneath said surface, said particles being at a concentration at said selected  
5 depth to define a substrate material to be removed above said selected depth; and  
6                   providing energy to a selected region of said substrate to initiate a  
7 controlled cleaving action at said selected depth in said substrate, whereupon said  
8 cleaving action is made using a propagating cleave front to free a portion of said  
9 material to be removed from said substrate.
  
- 1                   2.     The process of claim 1 wherein said particles are derived from  
2 a source selected from the group consisting of hydrogen gas, helium gas, water  
3 vapor, methane, hydrogen compounds, and other light atomic mass particles.
  
- 1                   3.     The process of claim 1 wherein said particles are selected from  
2 the group consisting of neutral molecules, neutral atoms, charged molecules, charged  
3 atoms, and electrons.
  
- 1                   4.     The process of claim 1 wherein said particles are energetic.
  
- 1                   5.     The process of claim 4 wherein said energetic particles have  
2 sufficient kinetic energy to penetrate through said surface to said selected depth  
3 underneath said surface.
  
- 1                   6.     The process of claim 1 wherein said step of providing energy  
2 sustains said controlled cleaving action to remove said material from said substrate to  
3 provide a film of material.
  
- 1                   7.     The process of claim 1 wherein said step of providing energy  
2 increases a controlled stress in said material and sustains said controlled cleaving

3        action to remove said material from said substrate to provide a film of material.

1                    8.        The process of claim 1 wherein said introducing step forms  
2        damage selected from the group consisting of atomic bond damage, bond substitution,  
3        weakening, and breaking bonds of said substrate at said selected depth.

1                    9.        The process of claim 8 wherein said damage creates stress in  
2        said substrate material.

1                    10.       The process of claim 8 wherein said damage reduces an ability  
2        of said substrate material to withstand stress without a possibility of a cleaving of said  
3        substrate material.

1                    11.       The process of claim 1 wherein said propagating cleave front  
2        comprises a plurality of cleave fronts.

1                    12.       The process of claim 1 wherein said introducing step causes  
2        stress of said material region at said selected depth by a presence of said particles at  
3        said selected depth.

1                    13.       The process of claim 1 wherein said energy is selected from the  
2        group consisting of a thermal source, a thermal sink, a mechanical source, a chemical  
3        source, and an electrical source.

1                    14.       The process of claim 13 wherein said chemical source is  
2        provided by particles.

1                    15.       The process of claim 13 wherein said chemical source includes  
2        a chemical reaction.

1                    16.       The process of claim 13 wherein said chemical source is

2     selected from the group consisting of a flood source, a time-varying source, a  
3     spatially varying source, and a continuous source.

1                   17.     The process of claim 13 wherein said mechanical source is  
2     selected from the group consisting of a rotational source, a translational source, a  
3     compressional source, an expansional source, and an ultrasonic source.

1                   18.     The process of claim 13 wherein said mechanical source is  
2     selected from the group consisting of a flood source, a time-varying source, a  
3     spatially varying source, and a continuous source.

1                   19.     The process of claim 13 wherein electrical source is selected  
2     from the group consisting of an applied voltage source and an applied electro-  
3     magnetic means.

1                   20.     The process of claim 13 wherein said electrical source is  
2     selected from the group consisting of a flood source, a time-varying source, a  
3     spatially varying source, and a continuous source.

1                   21.     The process of claim 13 wherein said thermal source or said  
2     thermal sink provides energy by radiation, convection, or conduction.

1                   22.     The process of claim 21 wherein said thermal source is selected  
2     from the group consisting of a photon beam, a liquid jet, a gas jet, an electron beam,  
3     a thermo-electric heater, an oven, and a furnace.

1                   23.     The process of claim 21 wherein said thermal sink is selected  
2     from the group consisting of a liquid jet, a gas jet, a cryogenic fluid, a super-cooled  
3     liquid, a thermo-electric cooling means, and a super-cooled gas.

1                   24.     The process of claim 23 wherein said thermal source is selected

2 from the group consisting of a flood source, a time-varying source, a spatially  
3 varying source, or a continuous source.

1 25. The process of claim 1 wherein said substrate is maintained at a  
2 temperature ranging between -200°C and 450°C during said introducing step.

1 26. The process of claim 1 wherein said step of providing said  
2 energy is maintained at a temperature below 400°C.

1 27. The process of claim 1 wherein said step of providing said  
2 energy is maintained at a temperature below 350°C.

1 28. The process of claim 1 wherein said step of introducing is a  
2 step(s) of beam line ion implantation.

1 29. The process of claim 1 wherein said step of introducing is a  
2 step(s) of plasma immersion ion implantation.

1 30. The process of claim 1 further comprising a step of joining said  
2 surface of said substrate to a surface of a target substrate to form a stacked assembly.

1 31. The process of claim 30 wherein said joining step is provided  
2 by applying an electrostatic pressure between said substrate and said target substrate.

1 32. The process of claim 30 wherein said joining step is provided  
2 by using an adhesive substance between said target substrate and said substrate.

1 33. The process of claim 30 wherein said joining step is provided  
2 by an activated surface between said target substrate and said substrate.

1 34. The process of claim 30 wherein said joining step is provided

2 by an interatomic bond between said target substrate and said substrate.

1 35. The process of claim 30 wherein said joining step is provided by a  
2 spin-on-glass between said target substrate and said substrate.

1 36. The process of claim 30 wherein said joining step is provided  
2 by a polyimide between said target substrate and said substrate.

1 37. The process of claim 1 wherein said substrate is made of a  
2 material selected from the group consisting of silicon, diamond, quartz, glass,  
3 sapphire, silicon carbide, dielectric, group III/V material, plastic, ceramic material,  
4 and multi-layered substrate.

1 38. The process of claim 1 wherein said surface is planar.

1 39. The process of claim 1 wherein said surface is curved or  
2 annular.

1 40. The process of claim 1 wherein said substrate is a silicon  
2 substrate comprising an overlying layer of dielectric material, said selected depth  
3 being underneath said dielectric material.

1 41. The process of claim 40 wherein said dielectric material is  
2 selected from the group consisting of an oxide material, a nitride material, or an  
3 oxide/nitride material.

1 42. The process of claim 1 wherein said substrate includes an  
2 overlying layer of conductive material.

1 43. The process of claim 42 wherein said conductive material is  
2 selected from the group consisting of a metal, a plurality of metal layers, aluminum,

3 tungsten, titanium, titanium nitride, polycide, polysilicon, copper, indium tin oxide,  
4 silicide, platinum, gold, silver, and amorphous silicon.

1 44. The process of claim 1 wherein said step of introducing  
2 provides a substantially uniform distribution of particles along a plane of said material  
3 region at said selected depth.

1 45. The process of claim 44 wherein said substantially uniform  
2 distribution is a uniformity of less than about 5%.

1 46. A method for forming a film of material from a single-crystal  
2 silicon wafer, the method comprising steps of:  
3 implanting hydrogen ions through a surface of the single-crystal silicon wafer  
4 to a selected depth underneath the surface, the hydrogen ions being at a concentration  
5 at the selected depth to define a layer to be removed above the selected depth;  
6 bonding the surface to a workpiece; and  
7 providing energy to a selected region of the substrate to initiate a controlled  
8 cleaving action at the selected depth in the substrate to free the layer from the  
9 substrate.

1 47. A device comprising a thin film of silicon, the thin film of  
2 silicon having a cleaved surface with a cleaved surface roughness less than about 60  
3 nm.

1 48. The device of claim 47 wherein the thin film of silicon is less  
2 than about 15 microns thick.

1 49. The device of claim 47 wherein the thin film of silicon is  
2 bonded to a target wafer.

1 50. A method for forming a film of material from a single-crystal

2 silicon wafer, the method comprising steps of:  
3       implanting hydrogen ions through a surface of the single-crystal silicon wafer  
4 to a selected depth underneath the surface, the hydrogen ions being at a concentration  
5 at the selected depth to define a layer to be removed above the selected depth; and  
6       directing a jet of high-pressure fluid at a selected region of the substrate to  
7 initiate a controlled cleaving action at the selected depth in the substrate to free the  
8 layer from the substrate.

1               51.     The method of claim 50 wherein the jet of high-pressure fluid is  
2 heated above a wafer temperature of the single-crystal silicon wafer.